

CLAIMS

1. An electro-active device comprising a plurality of flex circuits, each having a sheet of film and an electrode on at least one surface of the film, said plurality including at least first and second flex circuits, means forming a recess between said first and second flex circuits, and an electro-active element in said recess bonded to the flex circuits being mechanically and electrically coupled thereto.
2. An electro-active device according to claim 1, constituting a card wherein said element is bonded within the card by a thin layer of curable material.
3. An electro-active device according to claim 2, wherein the curable material is a structural polymer.
4. An electro-active device according to claim 1, wherein the electro-active element is a piezoelectric plate having a thickness under approximately one millimeter.
5. An electro-active device according to claim 4, wherein the piezoelectric plate has a thickness, and first and second cross dimensions, each cross dimension being greater than about ten times the thickness.
6. An electro-active device according to claim 1, wherein the electrodes have an electrode pattern, and said element is bonded to the flex circuit by a planarizing layer of curable material having a pattern complementary to the electrode pattern.
7. An electro-active device according to claim 4, wherein the electro-active element has a surface plane, and electrodes of said first and second flex circuits are patterned for applying an electric field which varies in said plane.

8. An electro-active device according to claim 4, wherein the electro-active element has a surface plane, and electrodes of said first and second flex circuits apply an electric field which varies in a direction normal to said plane.

9. An electro-active device according to claim 1, wherein the electrodes have a comb pattern.

10. An electro-active device according to claim 1, comprising two different electro-active elements in two different respective recesses and oriented to produce torsional actuation.

11. An electro-active device according to claim 1, further comprising a circuit element within the device.

12. An electro-active device according to claim 11, wherein the circuit element includes at least one of a shunt, a filter, an impedance matcher, a storage element, a power source, an amplifier, and a switch.

13. An electro-active device according to claim 11, wherein the circuit element includes a controller.

14. An electro-active device according to claim 1, wherein first and second electro-active elements are connected in different layers of the assembly for moving in different senses.

15. An electro-active device according to claim 1, constituting a device selected from among vanes, airfoils, shakers, steppers, stirrers and sonicators.

16. An electro-active device according to claim 1, having a thickness less than twice a combined thickness of electro-active elements stacked in the device.

17. An electro-active device according to claim 1, wherein the element is selected from among a stack, flexure, shell, plate and bender.

18. An electro-active device according to claim 1, configured as one of a pusher, vane, flap, lever, bender, bellows and combination thereof.

19. An actuator comprising
a flex circuit having conductors, and
a sheet strain element
wherein the flex circuit is assembled with at least some of its conductors in electrical contact with the sheet strain element and is bonded together therewith by a structural polymer into a flat card having an output face with a substantially shear-free mechanical coupling to the flat strain element.

20. A method of perturbing a device, such method comprising the steps of

(i) cementing a card in contact with a region of the device, the card enclosing a sheet of electro-active ceramic material with actuation electrodes, and

(ii) applying an electrical signal to the actuation electrodes to create strain energy in the electro-active ceramic material, whereby the strain energy from the electro-active ceramic material is coupled across a face of the card into said region to perturb the device.

21. A method of forming an actuator, such method comprising the steps of
forming a flex circuit having conductors arranged in a pattern
bonding an electro-active ceramic sheet in contact with at least some of said conductors, and
assembling the flex circuit and the electro-active ceramic sheet with a stiff structural polymer so as to constitute a card such that the sheet has a non-shear coupling to an outer face of the card and is electrically coupled over a region to electrodes of said flex circuit.

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22. The method of claim 21, wherein the step of assembling includes assembling circuit elements in said card.

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23. A method of forming an electro-active device, such method comprising the step of:
preparing first and second flex circuits with first and second electrodes and a recess therebetween, and
bonding at least one electro-active element in the recess in mechanical and electrical contact with said flex circuits over its surface area to form a unitary electro-active structure.

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24. The method of claim 23, further comprising the step of attaching circuit elements on said first and second flex circuits.

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25. The method of claim 23, wherein the step of bonding includes bonding plural pairs of electro-active elements.

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26. The method of claim 23, wherein said flex circuits are pliable in a region away from said recess.

27. The method of claim 23, wherein the step of preparing includes preparing at least three flex circuits.

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31. The method of claim 23, wherein the device constitutes a simple mechanical device selected from among pushers, vanes, flaps, levers, benders, bellows and combinations thereof.